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L6: Entry 2 of 15 File: USPT Oct 28, 2003

DOCUMENT-IDENTIFIER: US 6640248 B1
TITLE: Application-aware, quality of service (QoS) sensitive, media access control (MAC) layer

Abstract Text (1):
An application aware, quality of service (QoS) sensitive, media access control (MAC) layer includes an application-aware resource allocator, where the resource allocator allocates bandwidth resource to an application based on an application type. The application type can be based on input from at least one of: a packet header; and an application communication to the MAC layer. The application communication includes: a communication between the application, running on at least one of a subscriber workstation and a host workstation, and the MAC layer, running on at least one of a subscriber CPE station and a wireless base station. The bandwidth resource is wireless bandwidth. The resource allocator schedules bandwidth resource to an IP flow. The IP flow includes at least one of: a transmission control protocol/internet protocol (TCP/IP) IP flow; and a user datagram protocol/internet protocol (UDP/IP) IP flow. The resource allocator in scheduling takes into account resource requirements of at least one of a source application and a destination application of an IP flow. The resource allocator takes into account IP flow identification information extracted from at least one packet header field. The bandwidth resource is wireless bandwidth. The resource allocator allocates switching resource to an application based on an application type. The application type is based on input from at least one of: packet header; and an application communication to the MAC layer. The application communication includes a communication between an application, running on at least one of a subscriber workstation and a host workstation, and the MAC layer, running on at least one of a subscriber CPE station and a wireless base station. The application communication includes a priority class of the IP flow.

Parent Case Text (3):
The following applications of common assignee contain common disclosure: U.S. Patent Application entitled "Transmission Control Protocol/Internet Protocol (TCP/EP) Packet-Centric Wireless Point to Multi-Point (PtMP) Transmission System Architecture," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,477. U.S. Patent Application entitled "Quality of Service (QoS)--Aware Wireless Point to Multi-Point (PtMP) Transmission System Architecture," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,480. U.S. Patent Application entitled "Method for Providing Dynamic Bandwidth Allocation Based on IP-Flow Characteristics in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,126. U.S. Patent Application entitled "Method for Providing for Quality of Service (QoS)--Based Handling of IP-Flows in a Wireless Point to Multi-Point Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,118. U.S. Patent Application entitled "IP-Flow Identification in a Wireless Point to Multi-Point Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/347,856. U.S. Patent Application entitled "IP-Flow Characterization in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,150. U.S. Patent Application entitled "IP-Flow Classification in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,156. U.S. Patent Application entitled "IP-Flow Prioritization in a Wireless Point to

Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,476. U.S. Patent Application entitled "Method of Operation for Providing for Service Level Agreement (SLA) Based Prioritization in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,170. U.S. Patent Application entitled "Method for Transmission Control Protocol (TCP) Rate Control With Link-Layer Acknowledgments in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,481. U.S. Patent Application entitled "Transmission Control Protocol/Internet Protocol (TCP/IP)--Centric QoS Aware Media Access Control (MAC) Layer in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,159. U.S. Patent Application entitled "Use of Priority-Based Scheduling for the Optimization of Latency and Jitter Sensitive IP Flows in a Wireless Point to Multi-Point Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/347,857. U.S. Patent Application entitled "Time Division Multiple Access/Time Division Duplex (TDMA/TDD) Access Method for a Wireless Point to Multi-Point Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,475. U.S. Patent Application entitled "Reservation Based Prioritization Method for Wireless Transmission of Latency and Jitter Sensitive IP-Flows in a Wireless Point to Multi-Point Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,483. U.S. Patent Application entitled "Translation of Internet-Prioritized Internet Protocol (IP)-Flows into Wireless System Resource Allocations in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,479. U.S. Patent Application entitled "Method of Operation for the Integration of Differentiated services (Diff-serv) Marked IP-Flows into a Quality of Service (QoS) Priorities in a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,162. U.S. Patent Application entitled "Method for the Recognition and Operation of Virtual Private Networks (VPNs) over a Wireless Point to Multi-Point (PtMP) Transmission System," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,975. U.S. Patent Application entitled "Time Division Multiple Access/Time Division Duplex (TDMA/TDD) Transmission Media Access Control (MAC) Air Frame," filed Jul. 9, 1999, U.S. application Ser. No. 09/350,173. U.S. Patent Application entitled "Transmission Control Protocol/Internet Protocol (TCP/IP) Packet-Centric Wireless Point to Point (PtP) Transmission System Architecture," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,478. U.S. Patent Application entitled "Transmission Control Protocol/Internet Protocol (TCP/IP) Packet-Centric Cable Point to Multi-Point (PtMP) Transmission System Architecture," filed Jul. 9, 1999, U.S. application Ser. No. 09/349,474.

Brief Summary Text (14):
The resource allocator schedules bandwidth resource to an IP flow. The IP flow includes at least one of: a transmission control protocol/internet protocol (TCP/IP) IP flow; and a user datagram protocol/internet protocol (UDP/IP) IP flow. The resource allocator in scheduling takes into account resource requirements of at least one of a source application and a destination application of an IP flow. The resource allocator takes into account IP flow identification information extracted from at least one packet header field. The bandwidth resource is wireless bandwidth.

Detailed Description Text (18):
QoS can be a relative term, finding different meanings for different users. A casual user doing occasional web browsing, but no file transfer protocol (FTP) file downloads or real time multimedia sessions may have different a different definition of QoS than a power user doing many FTP file downloads of large database or financial files, frequent H.323 video conferencing and IP telephony calls. Also, a user can pay a premium rate (i.e. a so-called service level agreement (SLA)) for high network availability, low latency, and low jitter, while another user can pay a low rate for occasional web surfing only, and on weekends only. Therefore, perhaps it is best to understand QoS as a continuum, defined by what network

performance characteristic is most important to a particular user and the user's SLA. Maximizing the end-user experience is an essential component of providing wireless QoS.

Detailed Description Text (33):
4. Service Guarantees and Service Level Agreements (SLAs)

Detailed Description Text (34):
Service guarantees can be made and service level agreements (SLAs) can be entered into between a telecommunications service provider and a subscriber whereby a specified level of network availability can be described, and access charges can be based upon the specified level. Unfortunately, it is difficult to quantify the degree of network availability at any given time, and therefore this becomes a rather crude measure of service performance. It is desired that data delivery rate, error rate, retransmissions, latency, and jitter be used as measures of network availability, but measuring these quantities on a real-time basis can be beyond the capability of conventional network service providers (NSPs).

Detailed Description Text (35):
Another level of service discrimination desired by network service providers is a service level agreement (SLA) that provides for differing traffic rates, network availability, bandwidth, error rate, latency and jitter guarantees. It is desired that an IP-centric wireless broadband access system be provided that can provide for SLAs, enabling service providers to have more opportunities for service differentiation and profitability.

Detailed Description Text (78):
If multiple users share a wireless radio link as with the present invention, the inherently high BER of the medium could potentially cause frequent packet loss leading to unproductive TCP retransmission in congestion avoidance mode. Because wireless bandwidth can be a precious commodity, a IP-centric wireless QoS mechanism preferably provides for packet retransmission without invoking TCP retransmission and consequent and unnecessary "whipsawing" of the transmission rate. This, along with several other factors, makes desirable creation of an IP-centric wireless media access control (MAC) layer. One function of an IP-centric MAC layer can be to mediate local retransmission of lost packets without signaling TCP and unnecessarily altering the TCP transmission speed. A primary task of the IP-centric wireless MAC layer is to provide for shared access to the wireless medium in an orderly and efficient manner. The MAC layer according to the present invention, Proactive Reservation-based Intelligent Multimedia-aware Media Access (PRIMMA) layer, available from Malibu Networks Inc., of Calabasas, Calif., can also schedule all packet transmissions across the wireless medium on the basis of, e.g., IP flow type, service level agreements (SLAs), and QoS considerations.

Detailed Description Text (289):
Internet packets typically move on a first-come, first-serve basis. When the network becomes congested, Resource Reservation Protocol (RSVP) can enable certain types of traffic, such as video conferences, to be delivered before less time-sensitive traffic such as E-mail for potentially a premium price. RSVP could change the Internet's pricing structure by offering different QoS at different prices. Using SLAs, different QoS levels can be provided to users at CPE location stations depending on SLA subscription level.

Detailed Description Text (340):
Block diagram 800 lists an exemplary set of priorities 812 used by downlink flow scheduler 604 to place received data packets into priority class queues. Listed are the following set of example priorities: latency-sensitive UDP prority 812a, high priority 812b, intermediate priority 812c, initial hypertext transfer protocol (HTTP) screens priority 812d, latency-neutral priority 812e, file transfer protocol (FTP), simple mail transfer protocol (SMTP) and other e-mail traffic priority 812f

and low priority 812g. Persons skilled in the art will recognize that many different priority classes are possible, depending upon the QoS requirements of the end-users. Latency-sensitive UDP priority data can refer to data that has the highest priority because it is sensitive to jitter (i.e., time synchronization is important) and latency (i.e., the amount of time passage between IP data flows in reverse directions). High priority 812b can refer to, e.g., premium VPN service, and a high priority SLA service. Intermediate priority 812c can refer to, e.g., a value VPN service level and an intermediate level SLA service. HTTP screens priority 812d can refer to the download of HTTP data, for example, an initial HTTP screen, which is important for making an Internet user feel as if he has a great deal of bandwidth available for his Internet session. Latency-neutral priority 812e can refer to data that is neutral to latency, such as, e.g., e-mail traffic. FTP, SMTP priority 812f data includes data that is insensitive to latency and jitter, but requires a large amount of bandwidth to be downloaded accurately because of the size of a transmission. Finally, low priority data 812g can refer to data that can be transmitted over a long period of time, as when one network device transmits its status information to another network device on a 24 hour basis.

Detailed Description Text (352):
FIG. 9 illustrates how PRIMMA MAC IP flow scheduler 604 can also take into account a Service Level Agreement in prioritizing frame slot scheduling and resource allocation. FIG. 9 depicts SLA-mediated IP flow management diagram 900 including prioritization of uplink traffic being transmitted to wireless base station 302 from CPE subscriber locations 306a, 306b, 306c and 306d. For example, suppose subscribers of telecommunications services have subscribed to one of four SLA levels, P1 902a, P2 904a, P3 906a and P4 908a. In the illustrated example, suppose IP flows 902b are being sent to a subscriber at CPE location 306a and have an SLA priority level of P1 902a. Similarly, IP flows 904b, 906b and 908b are being sent to subscribers at CPE locations 306b, 306c and 306d and have SLA priority levels of P2 904a, 906a and 908a, respectively. PRIMMA MAC scheduler 604, 634 of wireless base station 302 can take into account SLA-based priorities in allocating available bandwidth to the subscriber CPE IP flows 902b, 904b, 906b and 908b. In the example illustration, IP flow 902b can be allocated frame slot 902c based on SLA priority 902a. Frame slots 904c, 906c and 908c can be similarly scheduled taking into account SLA priorities. Uplinked IP flow traffic can then be transmitted on to data network 142.

Detailed Description Text (353):
SLA-based prioritization can provide a valuable means for a telecommunications provider to provide differentiated services to a variety of customers. For example, it is possible that low priority traffic from a subscriber who has purchased a premium SLA service agreement, can be scheduled at a higher priority than high priority traffic from a subscriber which has only signed up for a value level or low cost SLA service priority.

Detailed Description Text (403):
Based on inputs from a hierarchical class-based priority processor, a virtual private network (VPN) directory enabled (DEN) data table and a service level agreement (SLA) priority data table (described below with respect to FIGS. 15A and 15B), the class 1, class 2, and class 3 packet flow queues are respectively assigned to class 1 downstream queue 1302, class 2 downstream queue 1304, and class 3 downstream queue 1306. Flow scheduler 604, 634 schedules these downlink data packets onto the downlink transmission subframe 1202.

Detailed Description Text (423):
Downlink flow scheduler 604 places the data packets of an IP data flow into a class queue, and based on a set of rules, schedules the data packets for transmission over the wireless medium to a subscriber CPE station using, e.g., an advanced reservation algorithm. The rules can be determined by inputs to the downlink flow scheduler from a hierarchical class-based priority processor module 1574, a virtual

private network (VPN) directory enabled (DEN) data table 1572, and a service level agreement (SLA) priority data table 1570. The advanced reservation algorithm is described further above with respect to FIG. 14.

Detailed Description Text (444):
The exemplary logical flow diagram 1560 for the downlink flow scheduler 604 of FIG. 15B comprises IP flow QoS class queuing processor module 1562, MAC downlink subframe scheduler module 1566, hierarchical class-based priority processor module 1574, VPN DEN data table module 1572, SLA priority data table 1570, CPE IP flow queue depth status processor 1582 and link layer acknowledgment processor module 1578.

Detailed Description Text (450):
Module 1562 can receive inputs from hierarchical class-based priority processor module 1574, VPN DEN data table 1572 and service level agreement (SLA) priority data table 1570. The queuing function of module 1562 can be based on these inputs.

Detailed Description Text (451):
SLA priority data table 1570 can use predetermined service level agreements for particular customers to affect the queuing function. A customer can be provided a higher quality of telecommunications service by, for example, paying additional money to receive such premium service. An algorithm running on module 1562 can increase the queuing priority for messages transmitted to such customers.

Detailed Description Text (452):
Virtual private network (VPN) directory enabled networking (DEN) data table 1572 can provide prioritization for a predetermined quality of service for a VPN for a company that pays for the VPN function. A VPN is understood by those skilled in the relevant art to be a private network, including a guaranteed allocation of bandwidth on the network, provided by the telecommunications service provider. VPN DEN data table 1572 permits module 1562 to provide higher quality of service for customer-purchased VPNs. As with SLA priority data table 1570, the queuing priority can be increased for such VPNs. For example, a platinum level VPN's lowest priority IP flow classes could also be given a higher priority than a high priority brass level VPN.

Detailed Description Text (453):
Both SLA priority data table 1570 and VPN DEN data table 1572 receive input from operations, administration, maintenance and provisioning (OAM&P) module 1108. This is a module that is kept off-line, and includes storage and revision of administrative information regarding new customers, or updates of information pertaining to existing customers. For example, the SLA priority of the customers and VPN information is updated from OAM&P module 1108.

Detailed Description Text (470):
Each time a subscriber CPE station 294d attempts to communicate in the uplink direction with wireless base station 302, it requests a reservation by inserting an RRB in the uplink subframe. Uplink frame scheduler 634 then schedules the reservation request in a future uplink subframe and notifies the CPE station 294d of the reservation in a downlink signal, uplink flow scheduler 634 located preferably at wireless base station 302, transmits a reservation slot in a particular future frame for the requesting subscriber CPE station 294d to transmit its uplink data. Uplink flow scheduler 634 assigns the reservation based on the same parameters as the downlink flow scheduler 604 uses in the downlink. In other words, uplink flow scheduler 634 determines the reservation slots based on the queue class priority and based on a set of rules, schedules the reservations for uplink transmissions from subscriber CPE station 294d using, e.g., an advanced reservation algorithm. The rules are determined by inputs to the uplink flow scheduler 634 from a hierarchical class-based priority processor module 1674, a virtual private network (VPN) directory enabled (DEN) data table 1672, and a

service level agreement (SLA) priority data table 1670. The advanced reservation algorithm is described with respect to FIG. 14.

Detailed Description Text (492):
The exemplary logical flow diagram for the uplink flow scheduler 634 of FIG. 16B comprises IP flow QoS class queuing processor module 1662, MAC uplink subframe scheduler module 1666, hierarchical class-based priority processor module 1674, VPN DEN data table module 1672, SLA priority data table 1670, CPE IP flow queue depth status processor 1682 and link layer acknowledgment processor module 1678.

Detailed Description Text (500):
The future slot(s) in the future frame(s) are assigned, e.g., based on inputs from hierarchical class-based priority processor module 1674, VPN DEN data table 1672 and service level agreement (SLA) priority data table 1670. These components function in a similar manner to hierarchical class-based priority processor module 1574, VPN DEN data table 1572 and service level agreement (SLA) priority data table 1570, described with respect to the downlink flow scheduler 604.

Detailed Description Text (502):
Module 1662 receives inputs from hierarchical class-based priority processor module 1674, VPN DEN data table 1672 and service level agreement (SLA) priority data table 1670. The queuing function of module 1662 is based on these inputs. These components function analogously to their counterparts in the downlink flow scheduling method. SLA priority data table 1670 and VPN DEN data table 1672 receive input from operations, administration, maintenance and provisioning (OAM&P) module 1108. OAM&P module 1108 provides updates to priorities when, e.g., a subscriber modifies its service level agreement or a VPN subscription is changed.

Detailed Description Text (547):
WAN interface 320 is bidirectionally linked to a bidirectional data frame FIFO 1002 which is bidirectionally coupled to both segmentation and resequencing (SAR) 1004 and QoS/SLA rules engine and processor 1008.

Detailed Description Text (548):
QoS/SLA rules engine and processor 1008 is also bidirectionally coupled to IP flow buffers 1014 and flash random access memory (RAM) 1010.

Detailed Description Text (549):
SAR 1004 is bidirectionally coupled to IP flow buffers 1014, flash RAM 1010, QoS/SLA rules engine and processor 1008 and PRIMA MAC scheduler ASIC 1012.

Detailed Description Text (552):
FIG. 11 is an exemplary software organization for a packet-centric wireless point to multi-point telecommunications system. The software organization of FIG. 11 includes wireless transceiver and RF application specific integrated circuit (ASIC) module 290, IP flow control component 1102, WAN interface management component 1104, QoS and SLA administration component 1106, system and OAM&P component 1108, customer billing and logging component 1110, directory enabled networking (DEN) component 1112, and wireless base station 320.

Detailed Description Text (556):
QoS and SLA administration component 1106 includes includes QoS performance monitoring and control module 1106a, service level agreements module 1106b, policy manager module 1106c and encryption administration module 1106d.

Detailed Description Text (557):
The QoS and SLA administration component 1106 provides the static data needed by the system in order to properly group particular IP-flows into QoS classes. Typically, during the provisioning phase of installing the system, the service provider will (remotely) download pertinent information about the subscriber CPE

station 294, including the subscriber CPE stations's SLA, any policy-based information (such as hours of operation or peak data transmission rate allowance.). Encryption keys or "strengths" can also be downloaded, which may be subscriber CPE station or service provider specific.

Detailed Description Text (561):
The customer billing and logging component 1110 allows the service provider to receive account, billing and transaction information pertaining to subscribers in the system. For service providers who bill on the basis of usage, cumulative system resource utilization data can be gathered. For specific types of activities (eg. video conferencing, multi-casting, etc.) there may be special billing data that is collected and transmitted to the service provider. This component also controls the availability of the system to subscribers through the operation of the subscriber authentication function. Once a subscriber is authorized to use the system, a new subscriber authentication entry is made (remotely) by the service provider. Likewise, a subscriber can be denied further access to the system for delinquent payment for services, or for other reasons. The service provider can also remotely query the system for specific account-related transactions.

CLAIMS:

1. An application aware, quality of service (QoS) sensitive, media access control (MAC) layer comprising: an application-aware resource allocator at the MAC layer, wherein said resource allocator allocates bandwidth resource to an internet protocol (IP) flow associated with a software application of a user based on IP QoS requirements of said software application, wherein said resource allocator allocates said bandwidth resource in a packet centric manner that is not circuit-centric and does not use asynchronous transfer mode (ATM).

7. The MAC layer according to claim 5, wherein said resource allocator in said resource allocation takes into account resource requirements of at least one of a source application and a destination application of said IP flow.

20. An application-aware media access control (MAC) layer for optimizing end user application internet protocol (IP) quality of service (QoS) to IP flows comprising: identifying means for identifying an application type of a software application associated with an IP flow; and allocating means for allocating resources to said IP flow, responsive to said identifying means, so as to optimize end user application IP QoS requirements of said software application, wherein said resource allocating means allocates resources in a packet-centric manner that is not circuit-centric and does not use asynchronous transfer mode (ATM).